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DATA PROCESSING PLANS FOR BALLISTIC WINDS STUDY

QUARTERLY REPORT NO. 1

By

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1 June 1965 to 31 August 1965

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U. S. ARMY ELECTRONICS COMMAND,

FORT MONMOUTH, N. J.

ABSTRACT

Detailed computer program specifications were written for a preprocessor to perform various editing and minor calculating functions on a basic set of rawinsonde data. These functions are described.

A formulation was made of the several parts of the Conditional Relaxation Analysis Method (CRAM) program that will be used to analyze the data. The procedures for the initial guess, correction, solution of Poisson's Equation by relaxation, and smoothing are discussed.

1.0 INTRODUCTION

Contract DA 28-043 AMC-01377 (E) is for the development of an improved, automated technique for computing ballistic winds, temperature and density in mountainous terrain.

The initial effort under this contract has been the development of data processing procedures. Two computer programs are being written for the IBM 7094. A preprocessor program will perform various editing and preliminary calculating functions on the basic data (as supplied) to yield a set of data in a format acceptable to the subsequent objective analysis program. The analysis program will then yield virtual temperature, density, and wind analyses necessary for the various ballistic calculations. These two programs are described in more detail in the following section.

2.0 DESCRIPTION OF COMPUTER PROGRAMS

2.1 The Preprocessor

Basic meteorological data, to be supplied by the sponsor, will comprise rawinsonde reports for a network of twelve stations in the Ft. Huachuca, Arizona area taken several times a day during January and February of 1965. Before this data can be fed into an objective analysis program, editing, converting and calculating must be performed. The preprocessor program now being written will first perform any conversion necessary to make the data, generated by a Burroughs B-5000, acceptable to the IBM 7094. The horizontal coordinates of the balloon at each recorded altitude are given in relative terms as horizontal northward and eastward displacements from the launch site for each tenth of a minute for the first three minutes and every minute thereafter. The next function of the preprocessor will be to convert these displacements to absolute locations in the objective analysis grid system. This grid system will be based on the Universal Transverse Mercator (UTM) grid system with a grid interval of 10 km.

At the same time, the vertical coordinate of the balloon, given in height above sea level, will be converted to height above ground along its trajectory. For this purpose, a gridded terrain map is being constructed from maps prepared by The Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C. with a basic grid interval of 2.5 km. This map will be placed on magnetic tape to use in these height determinations.

The next step is to compute zone wind components for each rawinsonde flight. The horizontal coordinates of the balloon and the elapsed time are computed for the base and top of each specified artillery zone. This computation is performed by interpolation using the previously-computed horizontal and vertical coordinates. The u- and v-zone wind components for each artillery zone are then computed from the horizontal distance travelled from the base to the top of the zone and the elapsed time within the zone.

The preprocessor will also compute the mean virtual temperature and mean density for each of the zones using the significant-level data supplied. For these determinations the zones are computed, not from height above ground, but rather, by reference to the height of the firing position.

In both the zone wind computations and the temperature and density computations, the location of the meteorological information for each zone is assigned the horizontal coordinates of the midpoint of the particular zone taken along the balloon trajectory, thereby taking into account the drift of the balloon.

The final role of the preprocessor is to write an output tape which will contain the zone winds, temperature and density for each station along with its grid locations. This information will be used as input to the objective analysis program.

2.2 The Objective Analysis Program

Objective analysis is concerned with defining the spatial distribution of a variable at a set of regularly spaced grid points, given an irregularly spaced set of observations. The analysis technique to be used in this study is one developed and applied by Thomasell and Welsh[1] called CRAM (Conditional Relaxation Analysis Method). CRAM is based on a generalized version of Carstensen's relaxation method.[2] We are modifying an existing two-dimensional CRAM program to extend it to three dimensions. The horizontal grid length will be 10 km while the vertical grid interval will be a function of the artillery zone heights.

We begin with an initial guess of the variable to be analyzed over an evenly spaced field of grid points, $\phi(i, j, k)$. The horizontal coordinates are represented by i and j and the vertical coordinate by k. There are several ways to generate the initial guess. One, which we are considering, is to employ a surface-fitting technique to the data. That is, we wish to find the three-dimensional polynomial surface which best fits the observed field of data where the equation for the surface is of the form

$$\phi(x, y, z) = a_0 + a_1 x + a_2 y + a_3 z + a_4 x^2 + a_5 y^2 + a_6 z^2 \qquad (2\text{-}1)$$

We will do this by using a screening regression technique to select those "predictors", x, y, z, etc., which significantly explain the variability of the "predictand", ϕ. The screening regression technique is outlined as follows.

From an array of possible predictors, the screening procedure selects first the one that has the highest linear correlation with the predictand in question. This predictor is

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[1]Thomasell, A., and J. G. Welsh, 1963: Studies of Techniques for the Analysis and Prediction of Temperature in the Ocean. Part I: The Objective Analysis of Sea-surface Temperature, Interim Report 7046-70, The Travelers Research Center, Inc.

[2]Progress Report, Fleet Numerical Weather Facility, U.S. Naval Postgraduate School, Monterey, Calif., April 1962.

then held constant, and partial-correlation coefficients between the predictand and each of the remaining predictors are examined; the predictor now associated with the highest coefficient is the second one selected. Additional predictors are chosen similarly until a selected predictor fails to explain a significant additional percentage of the remaining variance of the predictand.

The technique also gives the coefficients (a_0, a_1, etc.) for each of the selected "predictors". The initial guess field is now generated from the derived equation.

The initial guess field is then "corrected". For each observation, the difference between the observed value and value computed for that location by interpolating among the initial guess values at the surrounding grid points is computed. This difference is then translated to the nearest grid point and added to that grid point as a correction to the initial guess. If more than one difference is translated to the same grid point an average correction is applied. These modified grid-point values are then "flagged". Also initial-guess grid-point values on the six perimeter surfaces of the analysis volume are considered to have fixed values and are also "flagged". For all "flagged" grid points, ϕ does not change during the subsequent relaxation process. (see Fig. 2-1)

The next step is to compute for all non-flagged grid points new values which satisfy the Poisson Equation,

$$\nabla^2 \phi(i, j, k) = F(i, j, k) \tag{2-2}$$

where ϕ is the analyzed value of the variable in question at grid point (i, j, k), F is a forcing function defining some specified feature of the field of ϕ, and ∇^2 is the finite-difference Laplacian operator in three dimensions. The forcing function, F, is generally computed from the initial guess field as

$$\begin{aligned} F(i, j, k) = {} & \phi(i+1, j, k) + \phi(i-1, j, k) + \phi(i, j+1, k) + \phi(i, j-1, k) \\ & + \phi(i, j, k+1) + \phi(i, j, k-1) - 6\phi(i, j, k) \end{aligned} \tag{2-3}$$

The solution of Eq. (2-2) is accomplished by relaxation methods, as follows:

For each of the non-flagged grid points

(a) Compute the residual, R, for iteration n from

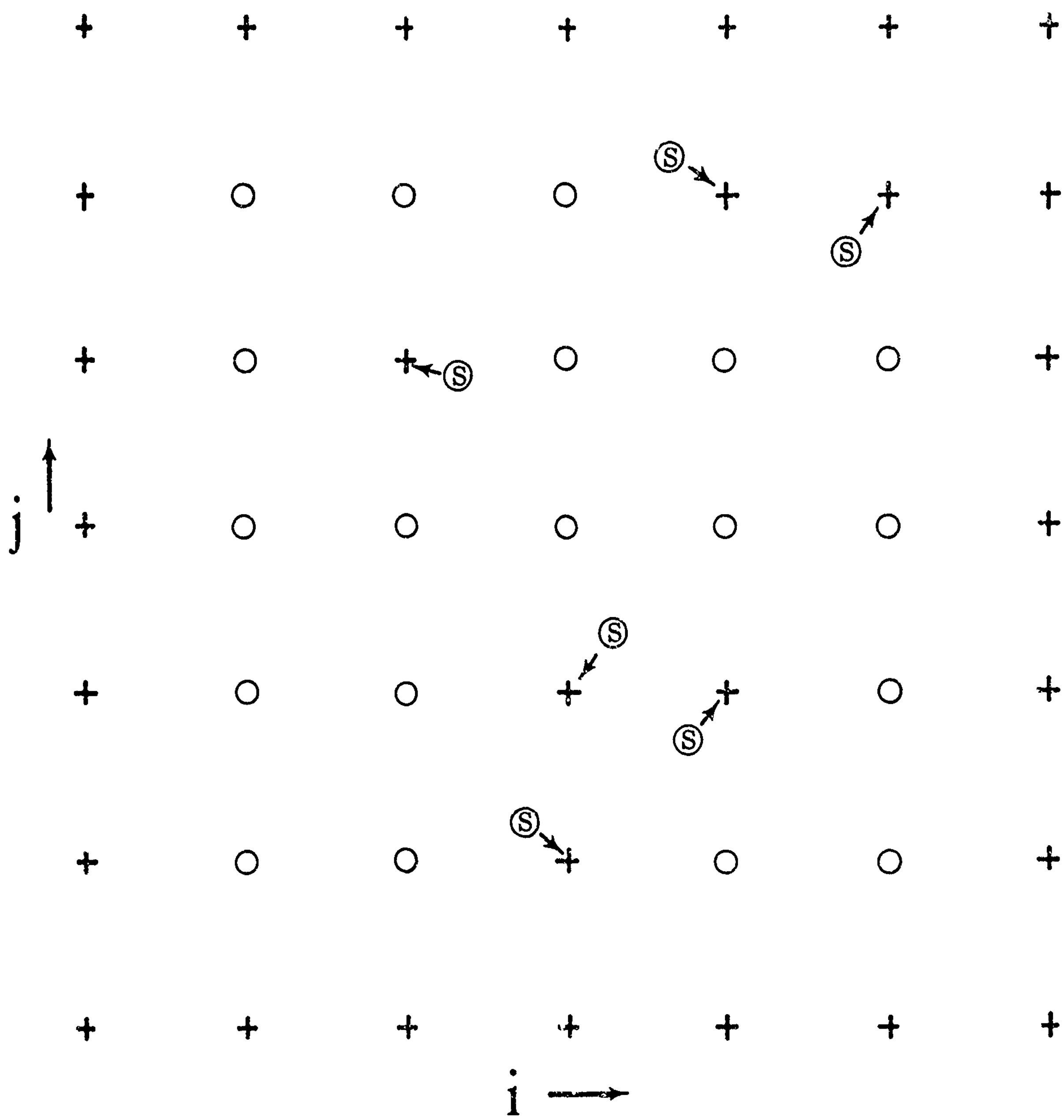

Fig. 2-1. Typical two dimensional field of ϕ (i, j). Grid points which have been flagged are denoted by + and those not flagged are denoted by O. Station observations are denoted by Ⓢ with an arrow pointing to the grid points for which values of ϕ are modified.

$$R^n(i,j,k) = \phi^n(i+1,\ j,k) + \phi^n(i,\ j+1,\ k) + \phi^n(i,j,\ k+1) + \phi^{n+1}(i-1,\ j,k) + \phi^{n+1}(i,\ j-1,k) + \phi^{n+1}(i,j,\ k-1) - 6\phi^n(i,j,k) - F(i,j,k). \tag{2-4}$$

(b) If $|R^n(i,j,k)| \leq \epsilon$ (where ϵ is the tolerance) proceed to the next grid point and return to (a) above.

(c) If $|R^n(i,j,k)| > \epsilon$, compute the (n+1) estimate of $\phi(i,j,k)$ from

$$\phi^{n+1}(i,j,k) = \alpha R^n(i,j,k) + \phi^n(i,j,k) \tag{2-5}$$

where α, the relaxation coefficient, is an input parameter. Then proceed to the next grid point and return to (a) above.

(d) When the first pass through the non-fixed grid points has been completed, return to (a) for a second pass if any residuals remain that exceed ϵ. Repeat passes as often as is required to reduce all residuals to ϵ or less.

The last phase of the analysis program is the application of a smoothing operator to eliminate from the analysis undesirable small-scale features introduced by small errors or by the analysis technique itself.

A simplified version of CRAM has been written for the IBM 1620 to compare the fields analyzed two-dimensionally with those analyzed three-dimensionally and to study the number of passes required as a function of the relaxation coefficient. We feel that three-dimensional CRAM analyses should be superior to the two-dimensional CRAM analyses as well as being computationally more efficient.

3.0 CONCLUSIONS

A preprocessing program has been coded to convert basic meteorological data into a form that can be processed efficiently by the objective analysis program.

The objective analysis program is a three-dimensional adaptation of the Conditional Relaxation Analysis Method (CRAM). This will be our principal analysis tool for studying ballistic corrections in mountainous terrain.

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Detailed computer program specifications were written for a preprocessor to perform various editing and minor calculating functions on a basic set of rawinsonde data. These functions are described.

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